

## Facilities for the Future of Science: A Twenty-Year Outlook

Along with our traditions of freedom, democracy, and the American spirit of enterprise, it is our scientific accomplishments that are most responsible for the improved prosperity, security, and quality of life that our Nation has enjoyed over the last century. Estimates are that fully half of the growth of the U.S. economy in the last 50 years is due to federal funding of scientific and technological innovation.

Yet the health and vitality of U.S. science and technology depends upon the availability of the most advanced research facilities. These very large and complex machines and instruments have enabled U.S. researchers to make many of the most important scientific discoveries over the past six decades, with spin-off technological advances creating entirely new industries and devices. Every day, for example, each of us relies on modern technology developed from the most fundamental research into the microscopic structure and properties of matter—from personal computers based on state-of-the-art electronics; to medical tools that image, help diagnose, and treat disease without surgery; to telecommunications technology that allows us to talk with friends and colleagues around the world from a device smaller than the size of a human hand.

The U.S. Department of Energy's Office of Science leads the world in the conception, design, construction, and operation of large-scale research facilities. Now, in *Facilities for the Future of Science: A Twenty-Year Outlook*, DOE is proposing a portfolio of 28 prioritized new scientific facilities and upgrades of current facilities spanning the scientific disciplines to ensure the U.S. retains its primacy in critical areas of science and technology well into the next century.

This prioritized list of new facilities and upgrades will help the Department plan its future scientific investments. While it is DOE's intent to give priority to these facilities, many steps need to occur prior to deciding whether and when to propose construction, including long-term budget estimates, project R&D, conceptual design work, engineering design work, and scientific reviews. In addition, funds for each facility need to be identified within the President's budget priorities, and any proposed projects would require approval by Congress.

Construction of these new facilities and upgrades of current facilities, integrated with the plans of other U.S. science agencies over the next twenty years, will sustain – in the best American tradition – the flow of seminal

scientific ideas and extraordinary technological innovation that are so critical to growing the U.S. economy and enhancing our way of life.

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The Department of Energy's Office of Science manages 10 national laboratories and builds and operates the world's finest suite of scientific facilities that researchers depend on to extend the frontiers of science. These state-of-the-art facilities are located at national laboratories and universities, shared with the science community worldwide, and contain technologies and capabilities that are available nowhere else.

The facilities include particle accelerators, synchrotron light sources, neutron scattering facilities, supercomputers, high-speed networks, and genome sequencing facilities. And they are of use in such diverse fields as materials sciences, chemistry, high energy and nuclear physics, fusion energy, biology, advanced computation, and environmental sciences. Each year, these DOE Office of Science facilities are used by more than 18,000 researchers and their students from universities, private industry, foreign nations, and other U.S. government agencies, including the National Science Foundation (NSF) and the National Institutes of Health (NIH).

The Department of Energy's Office of Science funds basic research in support of the Department's missions of national, economic, and energy security, scientific and technological innovation, and environmental clean up. As the steward of America's national laboratories, the Department of Energy has a special responsibility to plan for and propose Office of Science investments for the future that will serve to advance those missions for the U.S.

Today, in Oak Ridge, Tennessee, the Office of Science is building the Spallation Neutron Source (SNS), which is due to be completed in 2006. The SNS is the last, large-scale facility under construction by the Office of Science, and that has raised a salient question: What facilities are needed next for scientific discovery?

The answer is provided in *Facilities for the Future of Science: A Twenty-Year Outlook*, which anticipates the large-scale facilities that scientists will require across all fields of science supported by DOE over the next two decades. The facilities were selected based on two criteria: their scientific significance and their support of Department of Energy missions.



The process followed to produce this document was transparent and interdisciplinary. It benefited from discussions with the White House Office of Science and Technology Policy, the Office of Management and Budget, and members of Congress. It was informed by the counsel of DOE's sister science agencies, the NSF, NIH, and NASA, in areas where our missions and interests are complementary. And it was driven by the advice and guidance of the U.S. scientific community as represented by the six Office of Science Advisory Committees.

The vision of *Facilities for the Future of Science: A Twenty-Year Outlook* is clear: new and upgraded major user facilities are needed so that researchers can address several grand challenges facing DOE, the scientific community, and the world:

The international experiment ITER will demonstrate the scientific and technological feasibility of fusion energy, an abundant, safe, and environmentally attractive energy source that may be harnessed to produce both electricity and hydrogen.

The next generation of advanced scientific computational capability will be key both to supporting America's scientific enterprise in all areas of science and to our economic competitiveness.

New biological research facilities will enable scientists to take the recent spectacular advances in biology and genetics and apply them to DOE missions – for example, by creating microbes that will absorb excess carbon dioxide in the atmosphere, clean up the environment, and produce hydrogen for the clean-energy, hydrogen-based economy of the future.

High energy and nuclear physics facilities will further enhance our understanding of the nature of matter, energy, space, and time at the most fundamental level.

New basic energy science facilities promise to lead to advances in materials sciences, chemistry, and nanotechnology, yielding everything from better, stronger, lighter construction materials, to novel ways to diagnose and treat disease, to better approaches for environmental cleanup.

New knowledge generated by all the proposed facilities and upgrades also may be applied in valuable ways to nuclear power generation, carbon sequestration, and hydrogen production, distribution, and storage – three major DOE initiatives.

The 28 facilities and upgrades are listed here by priority. Some are noted individually; others are presented in “bands,” where the advice of the Office of Science Advisory Committees did not make it possible to

determinate relative priorities. In addition, the facilities are roughly grouped into three categories – near-, mid- and far-term priorities – according to the anticipated timeframe of the scientific opportunities they would address

## Priority

### Near-Term

- |   |      |  |
|---|------|--|
| 1 | FES  | International Thermonuclear Experimental Reactor |
| 2 | ASCR | UltraScale Scientific Computing Capability       |

- |              |     |      |   |
|--------------|-----|------|---|
| Tie for<br>3 | {   | HEP  | Joint Dark Energy Mission                                   |
|              |     | BES  | Linac Coherent Light Source                                 |
|              |     | BER  | Protein Production and Tags                                 |
|              |     | NP   | Rare Isotope Accelerator                                    |
| Tie for<br>7 | {   | BER  | Characterization & Imaging                                  |
|              |     | NP   | Continuous Electron Beam Accelerator Facility 12GeV Upgrade |
|              |     | ASCR | Esnet Upgrade   |
|              |     | ASCR | NERSC Upgrade   |
|              |     | BES  | Transmission Electron Achromatic Microscope                 |
| 12           | HEP | BTeV |   |

### Mid-Term

- |               |     |                 |  |
|---------------|-----|-----------------|--|
| 13            | HEP | Linear Collider |  |
| Tie for<br>14 | {   | BER             | Cellular Systems Analysis & Modeling   |
|               |     | BES             | SNS 2-4 MW Upgrade                     |
|               |     | BES             | SNS Target Station II                  |
|               |     | BER             | Whole Proteome Analysis                |
| Tie for<br>18 | {   | NP              | Double Beta Decay Underground Detector |
|               |     | FES             | Next Step Spherical Tokamak            |
|               |     | NP              | RHIC II                                |

### Far-Term

- |               |   |     |   |
|---------------|---|-----|---|
| Tie for<br>21 | { | BES | National Synchrotron Light Source Upgrade |
|               |   | HEP | Super Neutrino Beam                       |
| Tie for<br>23 | { | BES | Advanced Light Source Upgrade             |
|               |   | BES | Advanced Photon Source Upgrade            |
|               |   | NP  | eRHIC                                     |
|               |   | FES | Fusion Energy Contingency                 |
|               |   | BES | High Flux Isotope Reactor Guide Hall II   |
|               |   | FES | Integrated Beam Experiment                |

*Facilities for the Future of Science: A Twenty-Year Outlook* represents a snapshot – the DOE Office of Science's best guess today at how the future of science and the need for facilities will unfold over the next two decades. We know, however, that science changes, and that is why these proposals should be assessed periodically in light of the evolving state of science and technology.

DOE's Office of Science also recognizes that the breadth and scope of the vision encompassed by these 28 facilities and upgrades reflects a most aggressive and optimistic view of the future of the Office. We believe that both this vision and that view are warranted – for our children's sake and the sake of our Nation.

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